SUPER TYPHOON PAKA (05C)

I. HIGHLIGHTS

Paka formed in the Central Pacific southwest of Hawaii on 28 November 1997. Paka tracked steadily westward for two and one half weeks before slamming into the islands of Guam and Rota. As Paka's eye passed over northern Guam, destructive winds caused extensive damage to private and commercial buildings, infrastructure, crops, and vegetation. More intense than Typhoons Pamela (May 1976) and Omar (August 1992), Paka, with estimated maximum sustained surface winds of 130 kt (67 m/sec) gusting to 160 kt (82 m/sec) approached, but did not exceed, the intensity of Karen (estimated 135 kt (69 m/sec) gusting to 165 kt (85 m/sec)) in November 1962. No life was lost as a direct result of Paka's passage. Preliminary estimates of total losses run in the hundreds of millions of dollars.

II. TRACK AND INTENSITY

During the last week of November convection associated with an equatorial westerly wind burst flared up 1080 nm (2000 km) southwest of Hawaii. This led to the formation of twin tropical cyclones - Paka (05C), in the Northern Hemisphere, and Pam (07P) in the Southern. Pam (07P), in the summer hemisphere, became a hurricane and began recurving southeastward (Figure 3-05C-1). After issuing the first 17 advisories on Paka, the Central Pacific Hurricane Center transferred warning responsibility to the Joint Typhoon Warning Center as the system approached the international dateline (IDL). The first JTWC warning was number 18, valid at 1800Z on 06 December. After reaching 60 kt (31 m/sec) on 08 December, Paka began to weaken again. JTWC forecasters believed this weakening trend would continue, because upper level analysis and prognostic charts indicated that the cyclone would remain in a region of significant vertical shear. At 1800Z on 09 December, JTWC analyzed the cyclone as a 45 kt (23 m/sec) system and forecast this to remain constant for 36 hours, followed by a weakening trend. However, by 0600Z on 10 December, this thinking had begun to change, as upper level analysis showed that vertical shear was lessening. JTWC now depicted a 55 kt (28 m/sec) system which would peak as a minimal strength typhoon within 24 hours. Eighteen hours later, it became apparent that Paka was continuing to develop, and the 00Z warning on 11 December predicted it would peak at over 100 kt (50 m/sec). Majuro

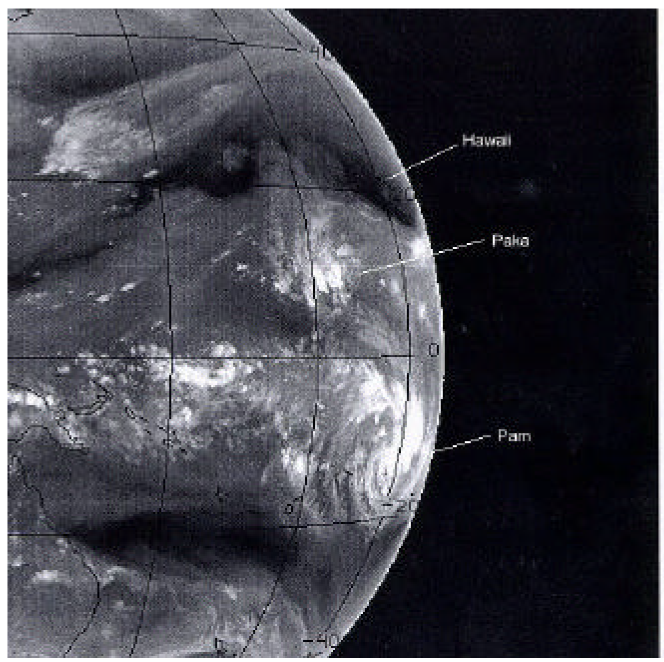


Figure 3-05C-1 Paka (05C) and Southern Hemisphere twin Pam (07P) early on 6 December, 1997 and Kwajalein atolls both received peak wind gusts of over 40 kt (20 m/sec) as Paka passed near on the 10th and the 11th, respectively.

After reaching an intensity of 115 kt (59 m/sec) on 12 December, Paka briefly weakened as along-track acceleration commenced. Despite forward speeds of 16 and 17 kt (30 and 31 km/hr), the typhoon started to intensify once again, peaking at 140 kt (72 m/sec) (160 mph) on 15 December. Paka was now a very serious threat to the southern Marianas. For Guam and Rota, the question rapidly changed from "if it arrives" to "when will it arrive?"

A day away from Guam, Paka began slowing, as anticipated, and there were signs of weakening. Now within NEXRAD Doppler radar range, the inner structure of Paka was revealed. There were concentric wall clouds - a primary approximately 40 nm (74 km) in diameter and a secondary fragmented inner wall cloud 10 nm (19 km) in diameter (Figure 3-05C-2). At 0600Z on 16 December, the center of Paka's eye was located 25 nm (46 km) south of the eastern point of Rota. The along-track speed was down to nine kt (17 km/hr), and the estimated intensity at 125 kt (64 m/sec) gusting to 150 kt (77 m/sec). At 161200Z, Paka had slowed to 6 kt (11 km/hr), and was at its closest point of approach (CPA) 15 nm (28 km) north of Agana, Guam. However, intensification was, once again, underway reaching an estimated maximum of 130 kt (67 m/sec) gusting to 160 (82 m/sec).

After seriously damaging the islands of Guam and Rota, Paka continued to intensify and reached a peak of 160 kt (82 m/sec) briefly on 18 December. Then, rapid weakening began and persisted until the cloud system completely dissipated four days later on 22 December. See Chapter 6 for a listing of the 6-hourly best track position, intensity, track direction and speed.

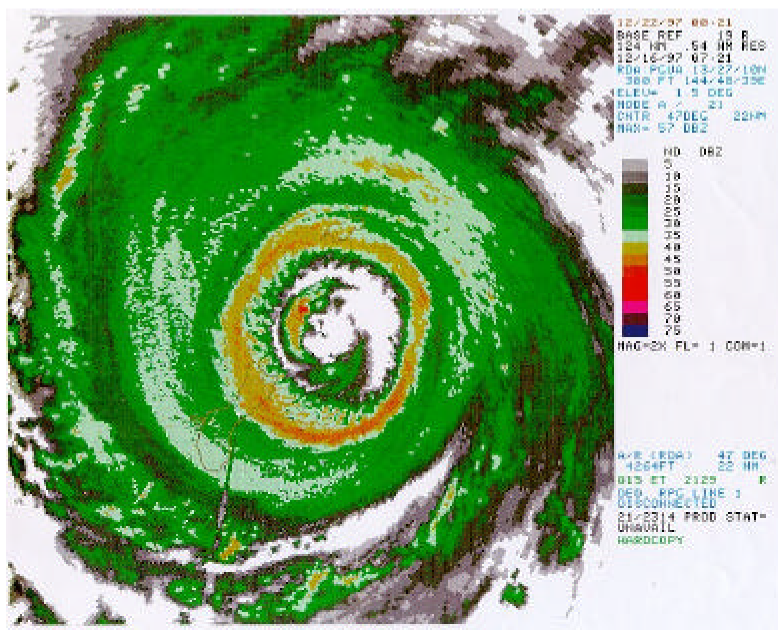


Figure 3-05C-2 NEXRAD imagery of Paka early on 16 December, 1997.

III DISCUSSION

a. Data Collection Difficulties

Considering the strength and duration of Paka's surface winds, it is not surprising that the wind records for areas that experienced passage of the primary wall cloud were fragmentary. The approach taken with these incomplete and noisy raw data records was to work sustained wind observations against the peak wind gusts, using a standard gust factor of 1.20 to 1.25 over water (Atkinson, 1974) and 1.60 overland. For example, gusts to 120 kt (62 m/sec) over water would be associated with a sustained surface wind of 100 kt (51 m/sec); overland gusts to 120 kt

(62 m/sec) would relate to 75 kt (39 m/sec) sustained wind. This technique identifies the representative data, for example: Commercial Port NWS HANDAR at Apra Harbor reported sustained/peak gust of 100/149 kt (51/77 m/sec) which is plausible; the Andersen AFB anemometer recorded 96/205 kt (49/105 m/sec) which is not considered representative. The Commercial Port sensor failed after recording four hours of 135 to 149 kt (69 to 77 m/sec) gusts in the wall cloud, Andersen AFB sensor lost power during passage of the western wall cloud. Additionally, the NWS sensor at Tiyan lost power during the onset of the primary wall cloud, the NPMOCW/JTWC anemometer at Nimitz Hill failed at 103 kt (53 m/sec) before the wall cloud arrived, the wind bird at the Apra Harbor tide guage failed in the wall cloud, and the NWS HANDAR at the University of Guam, Mangilao weathered the storm to report a peak gust to 123 kt (63 m/sec). In the final analysis the HANDAR instrument at Apra Harbor becomes the benchmark. It faithfully recorded peak gusts up to 149 kt (77 m/sec) until the winds began backing to the southwest, at which point it failed. This implies that the later southwesterly flow or second wind was stronger than the initial northwest to west wind (or first wind). This is borne out by the reports from other records at the Rota HANDAR and airport, DanDan and Merizo (Figure 3-05C-3). The only complete wind trace that records the peak winds in the wall cloud and the relative calm within the eye was from the Kuentos Communications, Inc. in Maite (Figure 3-05C-4). Relative to the lowest pressure which occurred at the CPA of Paka, the strength and duration of the highest winds on either side were compared. The wind from the southwest after the eye passage was more intense and of a longer duration. If this increase of 10 kt (5 m/sec) at Maite is applied to the Apra Harbor benchmark, a peak gust of 160 kt (82 m/sec) can be inferred.

b. Pressure Assessment

Microbarographs fortunately are less exposed than wind sensors which accounts for their survival, hence the pressure records were complete for Guam. The minimum sea-level pressure (MSLP) values (see Figure 3-05C-3) dropped from a high at DanDan (983 mb) and Merizo (980 mb) to Mangilao (953 mb), Apra Harbor (953 mb) and Tiyan (951 mb) to the lowest at Andersen AFB of 948 mb (Figure 3-05C-5). Using the MSLPs, which occurred at CPA, the passage of the center of Paka to the north of Guam can be followed across the checkerboard (Figure 3-05C-3). In addition, there is an empirical relationship (Dvorak, 1984) that can be used to relate the intensity (maximum sustained 1-minute mean surface winds over water) with the MSLP. The relationship has two scales: one for the Pacific and one for the Atlantic (Figure 3-05C-6). The reason for this is that the ambient pressure for the Pacific is in the mean lower than the Atlantic Ocean. Applying Dvorak's scale to Paka's 130 kt (67 m/sec) estimated intensity yields a 914 mb MSLP on the Pacific scale, which is much too low in relation to the values observed on Guam. However, a value for the Atlantic is 935 mb which is closer to what was observed. In summary, the basic reason for the difference between Pacific and Atlantic scales is that most tropical cyclones in the western North Pacific occur during the summer monsoon season when the ambient pressures are lower because of the presence of the monsoon trough. The Pacific scale doesn't address seasonal differences, therefore a bias exists. If a tropical cyclone, such as Paka, occurs in the winter, it follows that the scale will yield too low a MSLP. Therefore, a MSLP of 935 mb for Paka's 130-kt intensity appears reasonable.

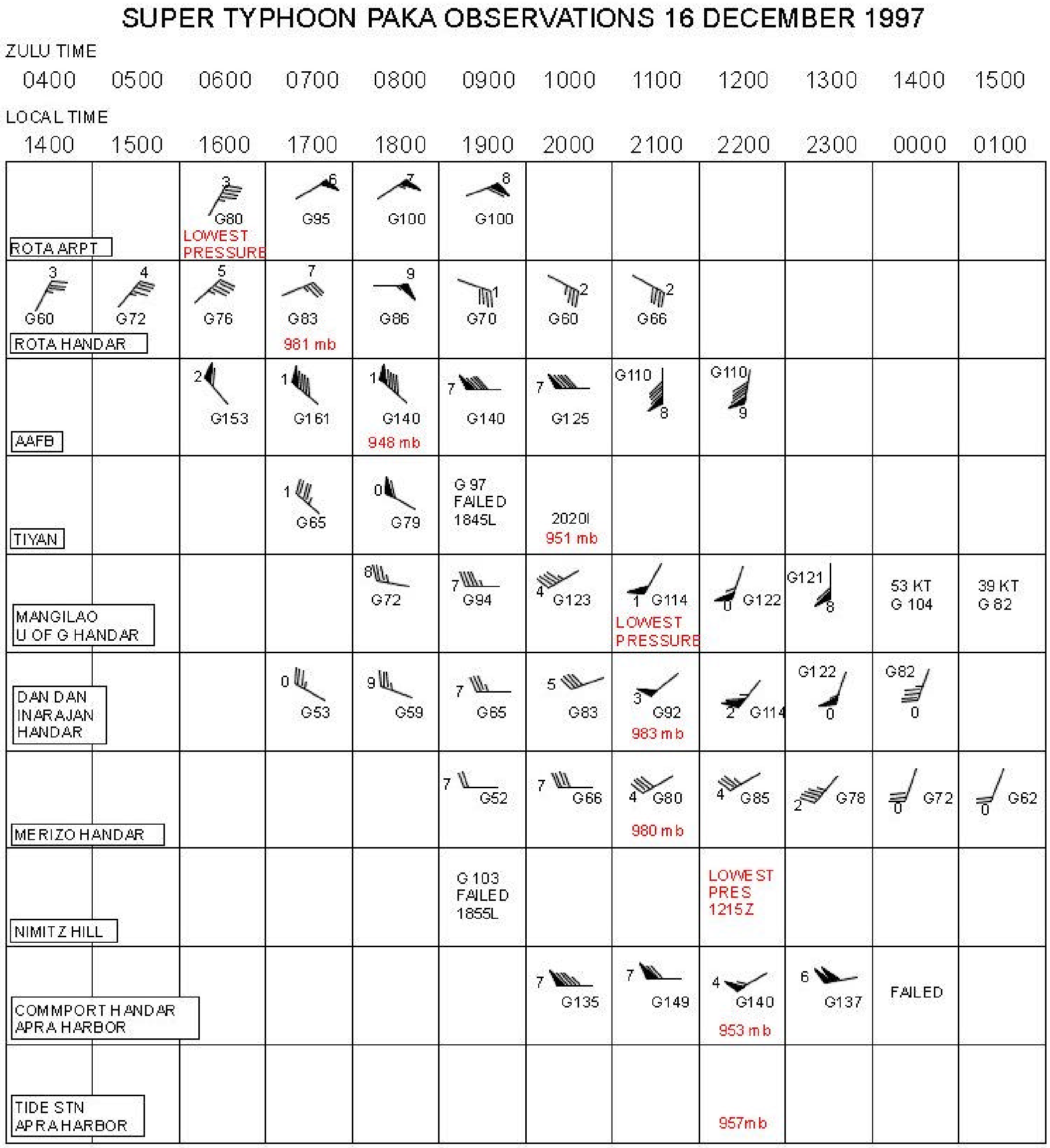


Figure 3-05C-3 Wind and pressure reports during the passage of Paka (05C) near Guam.

c. Radar Assessment

1) The NEXRAD Doppler radar, which is located at Mangilao and is maintained by Andersen AFB proved to be an invaluable tool for locating the center of Paka's eye and observing its convective structure. The last reflectivity product (Figure 3-05C-2) shows Pati Point, at the extreme northeastern end of Guam, just entering the relatively convection-free portion of the eye. The fragmented inner wall cloud is located over the Rota Channel to the northeast. The comparison radial velocity product (Figure 3-05C-7) indicates 144 kt (75 m/sec) inbound at the radar at 2000 feet (610 m) and 124 kt (64 m/sec) outbound. The 1-hour precipitation product (Figure 3-05C-8) indicates 1.50 to 2.00 inches (3.8 to 5 cm) in the wall cloud. Note: the absence of return over Rota to the northeast of the radar is due to lowest elevation beams being blocked by Mount Barrigada. No products were received after these because the NEXRAD radar went into standby mode and could not be remotely reset from the Unit Control Position at Andersen AFB. (The radar site weathered the storm without major damage.)

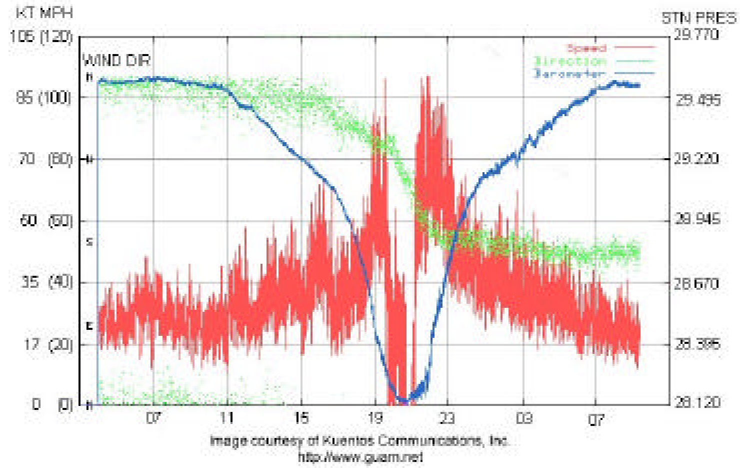


Figure 3-05C-4 This wind instrument, owned by Kuentos Communications, Inc, was the only one on Guam to recort the entire system passage.

2) The conventional FAA (Center-Radar Approach Control) CERAP radar located at Mount Santa Rosa proved invaluable for fixing Paka after the NEXRAD went into standby mode at 160721Z December. This support continued until the FAA radar failed at 161119Z.

IV IMPACT

Based on aerial and surface surveys, the following can be stated:

1) On Guam, as indicated by vegetation and crop blow downs and debris trails, the first wind (northwest through west) was less damaging than the second from the southwest through south. On Rota, the first wind (northeast through east) was less severe than the later second from the southeast. These observations support the fact that Paka was becoming more intense as it passed westward through the Rota Channel.

2) Moderate damage with pockets of heavy damage to private and commercial structures occurred on the northern half of Guam, which experienced outer wall cloud passage (Figure 3-05C-9). The slow passage (six hours) of the outer wall cloud across the center portion of the island allowed more time for high winds and rain to weaken structures.

3) In general, concrete roofs survived in areas where all structures with corrugated sheet iron lost their roofs. Steel framed buildings withstood the winds' onslaught and, although many lost sheet iron paneling and roofs, the structural integrity was maintained.

4) Minor distortion occurred to two smaller fuel storage tanks at Commercial Port, and one large, empty storage tank lost its fixed roof and collapsed. Damage to the power infrastructure was similar to that caused by Typhoon Omar in 1992.

5) Steel reinforced hollow concrete power poles failed under wind loading when they were not guyed, planted in shallow holes, or set in concrete without guys. These poles when guyed were observed to also fail when adjacent poles snapped, bringing the whole series down together.

In general, the damage assessment of northern Guam indicated a mixture of tropical cyclone scale categories 3 and 4 (Saffir-Simpson Hurricane Scale as modified by Guard and Lander, 1995) depending upon the exposure sites. This provides a wide range of maximum sustained wind speeds from 96-115 kt (49-59 m/sec) for category 3 to 116-135 kt (59-69 m/sec) for category 4.

Considering the magnitude and size of the debris trails, and the private structure and power infrastructure failures which occurred, it is indeed a tribute to preparation and common sense displayed by the combined population (160,000) of Guam and Rota that not a single life was lost as a direct result of Paka's passage.

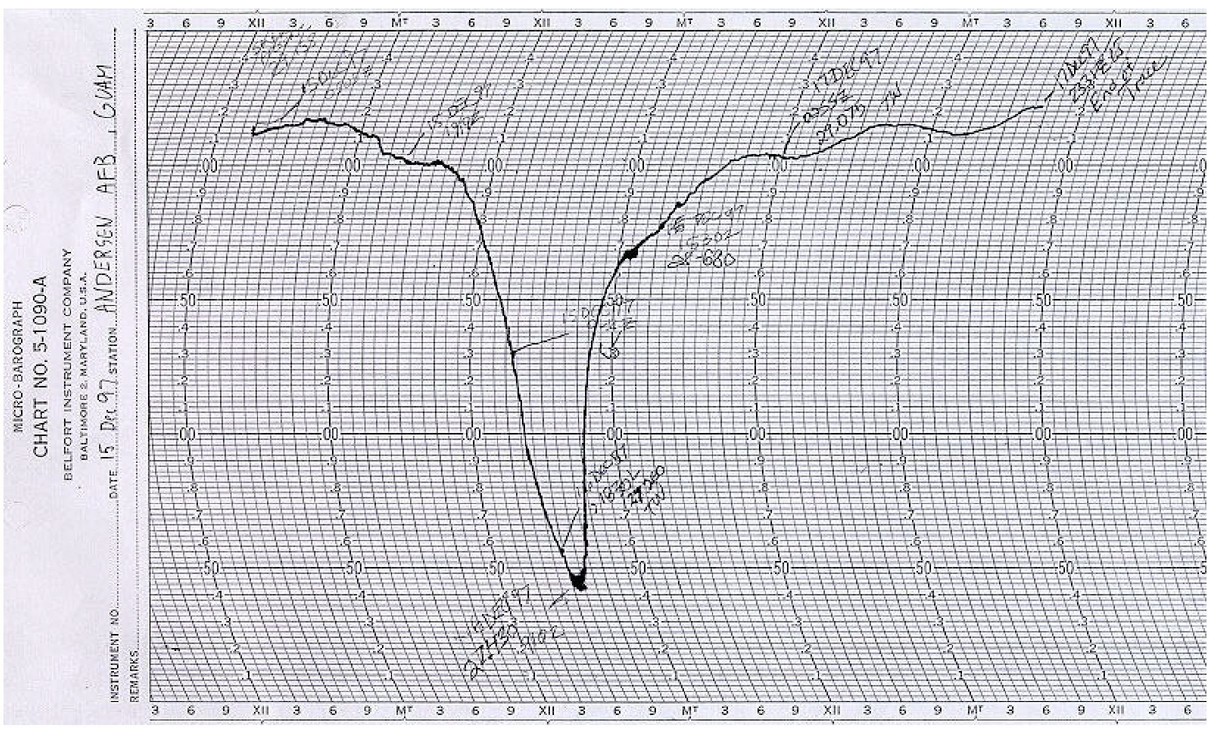


Figure 3-05C-5 Andersen AFB micro-barograph trace of Paka's (05C) passage.

C.I. NUMBER	MAXIMUM WIND SPEED	T-NUMBER	MINIMUM SEA-LEVEL PRESSURE (Atlantic)	(NW Pacific)
0	<25 kt			
0.5	25			
1	25	1		
1.5	25	1.5		
2	30	2	1009mb	1000mb
2.5	35	2.5	1005	997
3	45	3	1000	991
3.5	55	3.5	994	984
4	65	4	987	976
4.5	77	4.5	979	966
5	90	5	970	954
5.5	102	5.5	960	941
6	115	6	948	927
6.5	127	6.5	935	914
7	140	7	921	898
7.5	155	7.5	906	879
8	170	8	890	858

Figure 3-05C-6 Wind, pressure, and Dvorak relationship for both the Atlantic and Pacific.

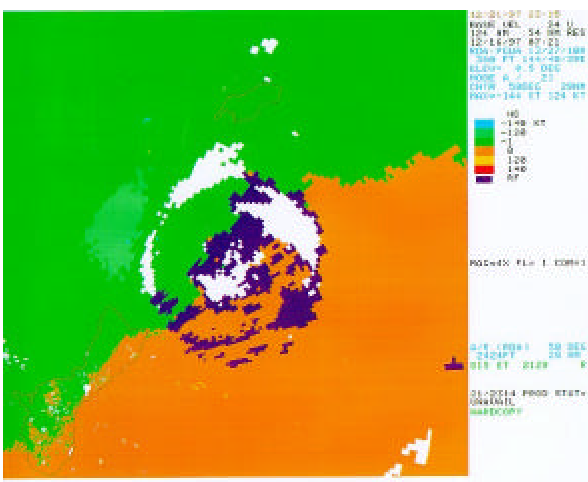


Figure 3-05C-7 NEXRAD radial velocity product for 0721Z on 16 December 97.

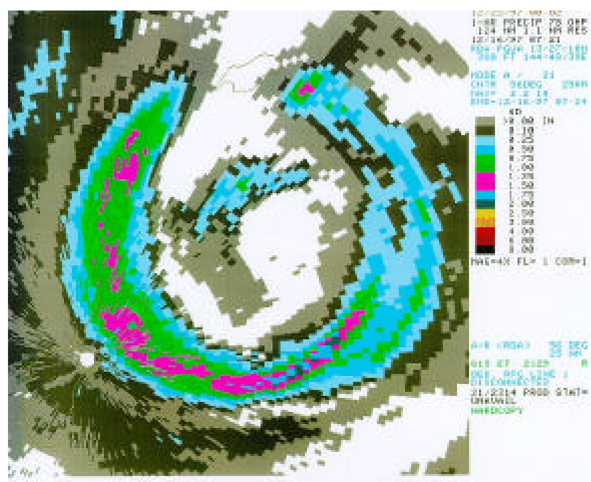


Figure 3-05C-8 NEXRAD one hour precipitation product for 0721Z on 16 December 97.

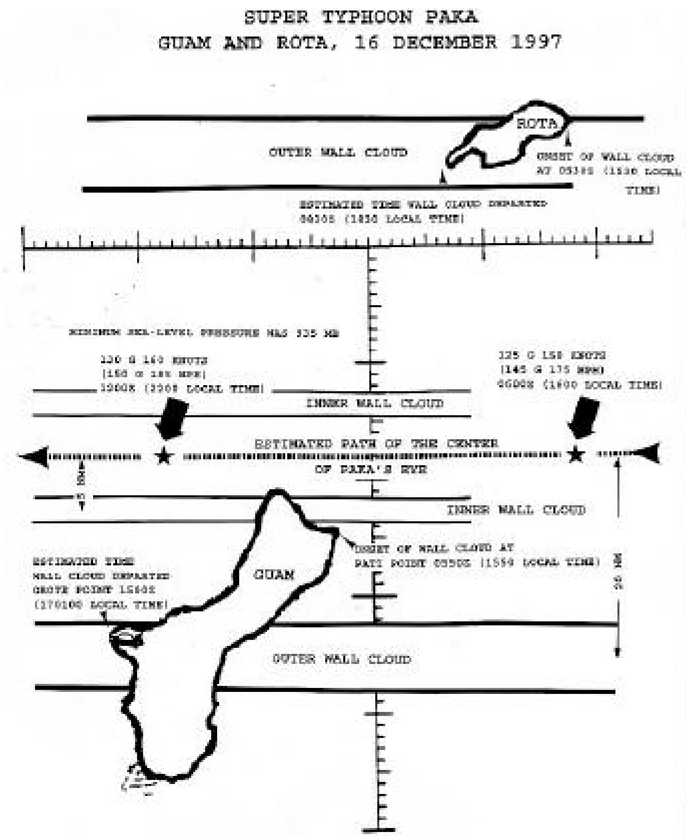
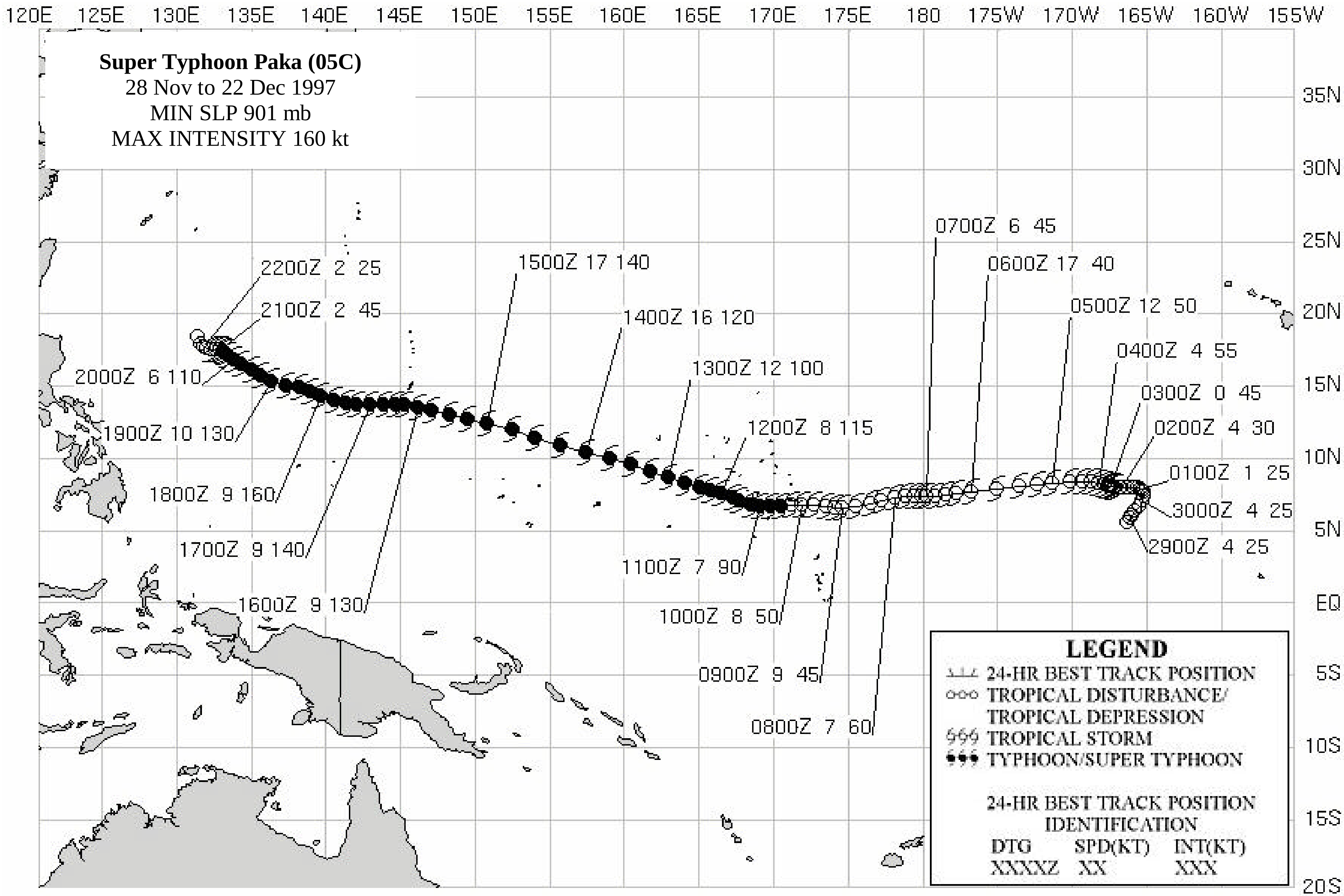


Figure 3-05C-9 Paka's (05C) track across Guam.



Super Typhoon Paka (05C)
28 Nov to 22 Dec 1997
MIN SLP 901 mb
MAX INTENSITY 160 kt
120E
125E
130E
135E
140E
145E
150E
155E
160E
165E
170E
175E
180
175W
170W
165W
160W
155W
35N
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
2200Z 2 25
2100Z 2 45
2000Z 6 110
1900Z 10 130
1800Z 9 160
1700Z 9 140
1600Z 9 130
1500Z 17 140
1400Z 16 120
1300Z 12 100
1200Z 8 115
1100Z 7 90
1000Z 8 50
0900Z 9 45
0800Z 7 60
0700Z 6 45
0600Z 17 40
0500Z 12 50
0400Z 4 55
0300Z 0 45
0200Z 4 30
0100Z 1 25
3000Z 4 25
2900Z 4 25
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XXX